

Claims

1           1. An apparatus for delivery of x-ray irradiation to a target, comprising:  
2           a waveguide for transporting x-ray irradiation, the waveguide comprising a first end  
3           and second end;  
4           a means for coupling x-ray irradiation into the first end of the waveguide, wherein  
5           the means for coupling x-ray irradiation into the first end of the waveguide comprises a first  
6           tapered cylinder; and  
7           a means for directing the x-ray irradiation exiting the second end of the waveguide  
8           to a target.

1           2. The apparatus according to claim 1, wherein the waveguide is a hollow  
2           waveguide.

1           3. The apparatus according to claim 1, wherein the first tapered cylinder is a hollow  
2           tapered cylinder.

1           4. The apparatus according to claim 3, wherein the first tapered cylinder reduces the  
2           cross-sectional area of the x-ray irradiation entering the first tapered cylinder as the x-ray  
3           radiation traverses the first tapered cylinder and is coupled into the first end of the  
4           waveguide.

1           5. The apparatus according to claim 3, wherein the means for directing the x-ray  
2           irradiation exiting the second end of the waveguide to a target comprises a reflecting tip such  
3           that the x-ray irradiation exiting the second end of the waveguide is incident on the reflecting  
4           tip and is reflected by the reflecting tip to the target.

1           6. The apparatus according to claim 5, wherein the reflecting tip comprises a first  
2           portion of glass surrounded by a second portion of glass having a different index of refraction  
3           than the first portion of glass such that an outer surface of the reflecting tip is cylindrical,

4 wherein x-ray irradiation exiting the second end of the waveguide and incident on the  
5 reflecting tip is reflected at a boundary between the first portion of glass and the second  
6 portion of glass.

1 7. The apparatus according to claim 6, wherein the target has a generally cylindrical  
2 shape and is generally concentric with the outer surface of the reflecting tip, wherein the  
3 reflecting tip reflects the x-ray irradiation in an approximately cylindrical pattern.

1 8. The apparatus according to claim 1, further comprising:  
2 a means for generating x-ray irradiation.

1 9. The apparatus according to claim 8, wherein the means for generating x-ray  
2 irradiation comprises a means for generating short pulses of optical energy and a means for  
3 using the short pulses of optical energy to generate x-rays from a plasma.

1 10. The apparatus according to claim 2, wherein the hollow waveguide comprises  
2 a reflective layer on an inner surface of the hollow waveguide.

1 11. The apparatus according to claim 10, wherein the reflective layer is a super  
2 mirror.

1 12. The apparatus according to claim 3, wherein the hollow tapered cylinder is a  
2 hollow linear tapered cylinder.

1 13. The apparatus according to claim 10, wherein the hollow waveguide propagates  
2 an approximately homogenous approximately Gaussian x-ray beam.

1 14. The apparatus according to claim 7, wherein the reflecting tip comprises a glass  
2 outer wall through which the x-ray irradiation passes after being reflected by the reflecting  
3 tip.

1           15. The apparatus according to claim 7, wherein the boundary between the first  
2           portion of glass the second portion of glass is conically symmetric about a central axis of the  
3           waveguide.

1           16. The apparatus according to claim 5, further comprising:  
2           a means for receiving x-ray irradiation exiting the second end of the waveguide and  
3           outputting the x-ray irradiation such that the outputted x-ray irradiation is incident  
4           on the reflecting tip.

1           17. The apparatus according to claim 16, wherein the means for receiving x-ray  
2           irradiation exiting the second end of the waveguide and outputting the x-ray irradiation such  
3           that the outputted x-ray irradiation is incident on the reflecting tip is a second tapered  
4           cylinder.

1           18. The apparatus according to claim 17, wherein the second tapered cylinder is a  
2           hollow tapered cylinder.

1           19. The apparatus according to claim 18, wherein the cross-sectional area of the x-  
2           ray irradiation beam outputted from the second hollow tapered cylinder is smaller than the  
3           x-ray irradiation beam received by the second hollow tapered cylinder.

1           20. The apparatus according to claim 18, wherein the x-ray irradiation beam exiting  
2           the second hollow tapered cylinder is an approximately homogeneous approximately  
3           Gaussian x-ray irradiation beam.

1           21. A method of selectively delivering x-ray irradiation to a specific location on an  
2           internal surface of a human or animal body, comprising:  
3           selecting a specific location on an internal surface of a human or animal body to  
4           which delivery of x-ray irradiation is desired;

5 generating x-ray irradiation external to the human or animal body;  
6 transporting via a waveguide the x-ray irradiation inside the human or animal body;  
7 and  
8 delivering the x-ray irradiation to the specific location.

1 22. The method according to claim 21, wherein the specific location is a portion of  
2 an inner arterial wall of an artery.

1 23. The method according to claim 22, wherein the inner arterial wall of the artery  
2 is irradiated after balloon angioplasty is performed on the artery.

1 24. The method according to claim 21, wherein the specific location is a tumor, and  
2 wherein sufficient x-ray irradiation is delivered to the tumor such that at least a portion of  
3 the tumor is necrotized.

1 25. The method according to claim 21, wherein generating x-ray irradiation  
2 comprises generating short pulses of optical energy and using the short pulses of optical  
3 energy to generate x-rays from a plasma.

1 26. The method according to claim 21, wherein transporting via a waveguide the x-  
2 ray irradiation inside the human or animal body comprises transporting via a hollow  
3 waveguide the x-ray irradiation inside the human or animal body.

1 27. The method according to claim 26, wherein the hollow waveguide has a  
2 reflective coating on an inner surface of the hollow waveguide.

1 28. The method according to claim 27, wherein the reflective coating on the inner  
2 surface of the hollow waveguide is a super mirror.

1           29. The method according to claim 26, wherein the x-ray irradiation generated  
2 external to the body is coupled into the waveguide via a tapered cylinder.

1           30. The method according to claim 29, wherein the tapered cylinder is a hollow  
2 tapered cylinder.

1           31. The method according to claim 22, wherein a distal end of the waveguide is  
2 inserted into the artery to be irradiated and guided within the artery until the distal end  
3 reaches the specific location.

1           32. The method according to claim 31, wherein the waveguide propagates an  
2 approximately homogeneous approximately Gaussian x-ray beam.

1           33. The method according to claim 31, wherein delivering the x-ray irradiation to the  
2 specific location comprises reflecting the x-ray irradiation exiting the distal end of the  
3 waveguide toward the specific location via a reflective tip.

1           34. The method according to claim 33, wherein the reflective tip comprises a glass  
2 outer wall through which the x-ray irradiation passes after being reflected by a reflective  
3 portion of the reflective tip.

1           35. The method according to claim 33, wherein the reflective tip is conically  
2 symmetric about a central axis of the waveguide.

1           36. The method according to claim 35, wherein an approximately cylindrical pattern  
2 of x-ray irradiation on the inner arterial wall is produced.

1           37. The method according to claim 31, wherein an x-ray irradiation beam exiting the  
2 distal end of the waveguide is coupled into a second tapered cylinder, wherein the x-ray

- 3 irradiation beam exiting the second tapered cylinder has a smaller cross-sectional area than
- 4 the x-ray irradiation coupled into the second tapered cylinder.

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